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RECENT RESULTS OF E866 ON HADRON PRODUCTION IN Au+Au REACTION AT AGS ENERGIES

ZIPING CHEN

*Brookhaven National Laboratory
Upton, NY 11973 USA*

For the E-802 collaboration

Data of hadronic particle production in Au+Au reactions at $E/A=11.6$ GeV has been measured. A systematic presentation for proton spectra in central reactions is made, as well as the rapidity distributions of particle yields for pions and protons. Centrality dependence of spectra for pions, protons, and deuterons is discussed. These results imply there is a large degree of stopping and a subsequent radial expansion in central Au+Au reactions.

1 Introduction

When two atomic nuclei with sufficiently large sizes approach each other head on at relativistic energies, it is conceivable that they will stop each other, converting the incident kinetic energy to heat and compress the interaction region formed by the strongly interacting nucleons. Given enough time for the system to come to a local thermalization, interesting phenomena, such as high baryon density, collective flow, or even the formation of quark-gluon plasma state, could arise from the enormous heat and compression. The amount of heat and compression, also the lifetime of the interaction region, are determined primarily by the sizes and the incident energy of the colliding nuclei. It is expected that at incident energies of 10-15 A GeV an interaction region of larger volume, higher density, and longer lifetime than previously measured reactions at AGS energies can be achieved by the collision of heavier atomic nuclei. These extraordinary conditions produced by the collision of atomic nuclei at relativistic energies offer an unique opportunity to study properties of nuclear matter far from normal state. With the installation of the booster, the Brookhaven Tandem-AGS (Alternating Gradient Synchrotron) complex is capable of accelerating Au ions with energies up to 11.6 GeV per nucleon.

2 Experimental Results

Experiment 866 at AGS is mainly a two-spectrometer experiment with event characterization to study particle production at high baryon density using Au beams (more on E866 ^{1,2}). The spectrometers can accurately determine the

Figure 1: On the left, measured invariant cross-section divided by the trigger cross section for identified protons in different rapidity intervals as a function of $m_t - m_0$ (see text). The bin width of the rapidity interval is 0.1, and δy is the distance of the measured rapidity of the spectra from the central rapidity $y_{nn} = 1.62$. The spectra are scaled down by a factor of 10 successively. On the right, invariant cross-section divided by the trigger cross section for identified pions and protons in the rapidity intervals $1.4 < y < 1.6$ and $1.2 < y < 1.4$. The spectra for $1.2 < y < 1.4$ are scaled down by a factor of 10. The open squares in the figure are the spectra for π^- , and the open circles are that for π^+ . Proton spectra are plotted with solid points.

momentum and identify the particles to 3-4 GeV/c depending on the species. The overall coverage in angle spans from 6° up to 54° .

2.1 Central Au+Au reactions at $E/A=11.6$ GeV/c

On the left side, Figure 1 shows the measured invariant spectra for protons at different rapidity intervals. On the vertical axis is the invariant cross-section divided by the trigger cross section where $\sigma_{trig} = 350$ mb corresponding to 6% of the total interaction cross section. On the horizontal axis, m_t is the so-called transverse mass defined as $m_t = \sqrt{p_t^2 + m_0^2}$, where p_t is the transverse momentum and m_0 is the rest mass of the identified particle. It should be pointed out that the beam rapidity for Au ions at $E/A=11.6$ GeV is about 3.2. Since in the reaction the projectile is identical to the target, the cross-section is therefore symmetric around the mid-rapidity, $y_{nn}=1.6$. δy is the distance of measured rapidity from the central rapidity $\delta y = |y - y_{nn}|$.

To inspect the shapes of the particle spectra in more details, the measured particle distributions for pions, and protons are displayed in right hand side

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Figure 2: Rapidity distribution dN/dy for p+p, Si+Al (peripheral) at $E/A=14.6$ GeV, Si+Al (central) at $E/A=14.6$ GeV, and Au+Au (central) at $E/A=11.6$ GeV. The rapidity on the x-axis is normalized to the beam rapidity in order to compare systems measured at slightly different energies. The left panel is for π^+ , and the right panel is for protons. The open points in the lighter systems are reflection of the solid points around mid-rapidity.

Figure 3: Proton (left) and deuteron (right) spectra at rapidity $y=1.3$ for four different rapidity cuts in Au+Au reactions at $E/A=11.6$ GeV. As indicated in the figure, the spectra are multiplied by a factor of 2 successively. The centrality is defined by measuring the hadronic energies in the forward direction with a Zero-degree Calorimeter. The lines are single exponential fits to the spectra.

Figure 4: Comparison of measured inverse slope parameters for π^+ , protons, deuterons at $y=1.3$ for several reactions and Au+Au reactions of different centralities. The x-axis is a simple estimate of the number of participants involved in the reactions. The four groups of solid point are extracted from spectra in the previous figure. The diamond points are from central Si+Au reactions, and the open square is from p+Au reactions at $E=14.6$ GeV.

of Figure 1 as a function of $m_t - m_0$ for rapidity intervals of $1.2 < y < 1.4$ and $1.4 < y < 1.6$. Clearly, the proton spectra are much flatter compared with those for pions. They tend to bend down at low $m_t - m_0$, and deviate from a description of purely exponential shape. Spectra for pions show a deviation at low $m_t - m_0$ too, however they rise instead. The rising at low $m_t - m_0$ for π^+ is much less. One of the reasons for the rising of both pions at the low $m_t - m_0$ could be that the decay of resonances such as deltas prefers to produce relatively low momentum pions⁶. The difference between the pions could be partially due to the Coulomb interaction with the rest of the co-moving media which in average is positively charged. In a very simple calculation, one could assume that pions interact with a co-moving source of an effective charge. This is much too simple a picture without any dynamical consideration, but a charge of the order 10-15 could account for most of the difference. Although proton and pion spectra have different shapes overall, it is interesting to point out that at high $m_t - m_0$ region above $0.7 \text{ GeV}/c^2$, all the particles seem to share a similar slope in their spectra.

By integrating a two-exponential parametrization of the spectra over $m_t - m_0$ in each rapidity bin, one can obtain the distribution of particle yield over rapidity, dn/dy . The yield, dn/dy , is proportionally dependent on the absolute

normalization of the spectra. We estimate that our systematic error in the normalization is about (10–15)% overall. The error bars shown in Figure 2 are statistical only. It is clear that protons for central Au+Au reactions are peaked at mid-rapidity. This is consistent with the picture of complete stopping when two Au nuclei approach each other head on. When this happens, enormously high baryon density exists during the collision, leading to the large amount of incident energy converted into heat and compression. Also compiled in Figure 2 are rapidity distributions for protons and pions for several symmetric systems at AGS energies, namely p+p, Si+Al (approximately symmetric) at $E/A=14.6$ GeV⁵. As the number of participants increases, the evolution of the proton distribution shows nicely the transition from almost transparency in p+p collisions to almost complete stopping in Au+Au reactions. In the pion sector (left panel), the yield of the pions has increased more than a factor of 10 from p+p to Au+Au, but the shapes of the distribution are not much different over the measured rapidity range. This is interesting, considering the drastic change on the proton distribution.

2.2 Centrality Dependence In Au+Au at $E/A=11.6$ GeV/c

In the experiment we can perform off-line software cuts on the centrality defined by the hadronic energies measured in a small solid angle at the forward direction by the Zero-degree Calorimeter¹. Four cuts ranging from peripheral to central reactions are selected for this presentation, and to get a rough idea they correspond to the number of participants indicated in Figure 4, which is calculated by assuming the calorimeter measures the energy carried by spectator nucleons. In Figure 3, invariant cross-sections are displayed for both protons and deuterons at rapidity $y=1.3$ for these four cuts. In the peripheral cut, both protons and deuterons show an exponential shape with a very steep slope. As the collision becomes more central, the spectra become less steep, and a deviation from exponential shape shows up in the central reactions. To put the change of spectrum shape in perspective, the lines in Figure 3 indicate exponential fits to the spectra in spite of some apparent deviation. Figure 4 compiles the inverse slope parameters of π^+ , protons, and deuterons for these centrality cuts in addition to reactions of lighter systems: p+Au³ and central Si+Au⁵ at $E/A=14.6$ GeV. All these parameters are essentially the same in p+Au reactions. There is basically no significant change of the parameters for π^+ regarding to all the systems, and the parameters for protons keep increasing for larger number of participants. The increase becomes more substantial for deuteron spectra. The systematics indicates^{7,8,9} the influence of radial flow for reactions of larger number of participants.

3 Summary

I have presented proton spectra systematically for central Au+Au reactions. A detailed inspection reveals the spectra deviate from exponential shape at low $m_t - m_0$ in central Au+Au reactions. The dependence of inverse slope parameters on centrality, in conjunction with measurements of reactions induced by lighter ions, suggests the influence of radial flow increases with the number of participants.

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